SQUALL LINE AND BOW ECHO
WSR-88D DOPPLER RADAR CHARACTERISTICS

National Weather Service
Louisville, Kentucky

REFLECTIVITY CHARACTERISTICS:

1. During a bow echo's incipient stage, a strong downburst may descend within or on the rear flank of the convective echo, resulting in an initial bulging echo pattern.

2. Bow echoes exhibit a bulging/bowing of the reflectivity gradient forward/downwind from the rest of the squall line. Usually, a strong low-level reflectivity gradient is present on the leading edge of intense convection indicating strong convergence and a vertical updraft.

3. Subtle weak echo regions (WERs) may be present on the leading edge of the reflectivity gradient marking the location of significant storm-relative inflow and the updraft zone.

4. Rear inflow notches (RINs)/weak echo channels (WECs) frequently are noted behind the leading intense convection, which usually are co-located with local enhancements in the rear inflow jet (RIJ).

5. Within an overall serial-type squall line, there may be several bowing echo segments embedded.

6. Bow echoes often are associated with significant damaging surface winds (assuming a well-mixed boundary layer) near the apex of the bow (i.e., along the RIJ), and possible non-supercell tornadoes along or north (cyclonic side) of the apex.

7. The leading convective line remains intense if the low-level cold pool beneath the convection balances the ambient vertical wind shear, so that the outflow boundary and intense updrafts remain on the leading edge of the convective line. An outflow boundary propagating ahead of the line may initiate new cells downwind but will eventually diminish updrafts and the intensity within the main line.

8. There may or may not be a relatively large "stratiform" precipitation area (albeit still some thunder and lightning) behind the leading convective line depending on the amount of storm-relative elevated front-to-rear flow. Squall lines that exhibit significant stratiform rainfall behind the entire length of the line are referred to as symmetric, while those with significant trailing rainfall only with the northern portion of the line are referred to as asymmetric. Serial-type "cool season" squall lines usually are associated with more training stratiform precipitation than progressive "warm season" events.

VELOCITY CHARACTERISTICS:

1. A mid-altitude radial convergence (MARC) signature may be evident in WSR-88D storm-relative velocity map (SRM) data at an altitude of about 3-7 km. Strong (over 50 kts; 25 m/s), persistent, deep-layered radial velocity differences (V_{in} + V_{out} along similar radials, i.e., MARC) within an area of convection can signify entrainment of environmental air that can enhance negative buoyancy through evaporation, resulting in downdraft acceleration, i.e., a downburst. Rear inflow in the system coupled with substantial MARC can accentuate the downburst. This causes the onset of damaging surface winds and the development of a low-level bow structure in reflectivity data. However, wind damage can occur before significant low-level bowing appears. Thus, the identification of spatially and temporally coherent MARC in convective systems is crucial to anticipating subsequent wind damage. MARC can precede the onset of surface wind damage by up to 15-20 minutes. MARC is also very useful in anticipating possible microbursts associated with severe pulse storms. Decreasing WSR-88D vertically integrated liquid (VIL) values in conjunction with significant MARC may signify a collapsing storm that is about to produce a downburst.

2. Local enhancements in the rear inflow jet (RIJ) tend to develop along and behind axes of bowing line segments, especially those associated with significant trailing stratiform precipitation. Convective downdrafts can intensify wind flow and damage associated with RIJs along the leading bow apex.

3. If the ambient wind shear is moderate-to-strong, the RIJ tends to remain elevated up to near the leading edge of the bow echo, then rapidly descends at the updraft/downdraft interface causing significant wind damage. Systems with elevated RIJs tend to be long-lived with rapid multicell growth along the leading edge of the system.

4. If the ambient shear is weak, the RIJ tends to descend and spread out along and behind the leading line, still with possible wind damage but less intense/shorter-lived than for stronger sheared MCSs.

5. Squall lines often contain two main airflow streams relative to the moving convective system. The first stream is rear-to-front associated with the RIJ. Above this stream is storm-relative front-to-rear flow. This stream has warm, moist origins ahead of the squall line, rises up rapidly within the leading convection, then exhibits a much more gently sloped ascent behind the line resulting in trailing stratiform precipitation.

MESOCYCLONE CHARACTERISTICS:

1. Cyclonic circulation (mesocyclone) formation and possible tornadogenesis within squall lines usually occur in association with bowing line segments given sufficient forcing, instability, and wind shear.

2. For leading line (bow echo) tornadoes, the initial circulation typically develops as an area of enhanced cyclonic-convergence in the lower portions of the storm along/just north of the bow apex, then rapidly intensifies and deepens in altitude, partly due to rapid vertical stretching in the updraft. The circulation may be wrapped within precipitation. The vortex eventually broadens and weakens as it propagates rearward with respect to the leading line. Tornado occurrence is most likely during the intensifying and deepening stage, when tight shears and strongest rotational velocities exist.

3. Tornadoes sometimes can be tucked within a subtle weak echo region (WER) on the front forward flank of an organized bow containing high precipitation (HP) supercell characteristics. Tornadoes also are possible within moderate-to-heavy precipitation under or near a rapidly rotating comma head reflectivity signature.

4. Convective cell or boundary interactions with bow echoes may further enhance convergence and vertical stretching allowing for more rapid development and spin-up of mesocyclones/cyclonic circulations.

5. Vortex evolution along an organized, long-lived bow echo can be cyclic, i.e., the initial circulation develops and intensifies, propagates along the bow, and eventually weakens. However, new circulations can develop quickly along the bow apex just to the south and/or east of the initial vortex go through the same life cycle. This can result in a series/family of transient tornadoes.

6. Tornadoes associated with bow echoes frequently are relatively short-lived and usually of F0-F2 intensity. Tornadic damage usually is embedded within and/or on the northern fringe of maximum straight-line wind damage associated with the bow apex and rear inflow jet. While tornado damage within bow echoes can be significant, the large majority of damage from bow echoes is from straight-line winds.